Fall 2020

Integration of Hog Market between China and the United States 2000-2014

Jiacheng Tian

Integration of Hog Market between China and the United States 2000-2014

Jiacheng Tian

Abstract

This study aims to ascertain the possible existence of integration between the hog markets in China and the United States. Using national monthly data from January 2000 to December 2014, our results indicate that hog prices between China and the U.S. are cointegrated. Such a result suggests no arbitrage between the two markets. We discuss the reasons why such arbitrage abandons; and conclude that it can be postulated the empirical evidence in integrated U.S. soybean prices alongside other factors may contribute to this result.

Keywords: hog, integration, china, cointegration, vector error correction (VECM), price transmission, soybean

1. Introduction

China is the country with the highest levels of pork consumption and production in the world. Prior to 2000, individual hog farms completely dominated the pork industry. Production inputs were heavily reliant on farmers' backyard homesteads and on locally purchased piglets. This model allowed extra leisure time for hog farmers, as it required a relatively low level of social resources and investments. This meant that there was not much competition among local agricultural enterprises. Between 2000 and 2014, numerous local cooperatives emerged. They invested a significant amount in the building of hog barns and pivoted to full-time hog-raising.

Although the utilization of social resources and investments was improved by cooperatives, individual hog farms still dominated the industry until 2014.

Since 2014, industrial hog farming operations have been actively promoted by the Chinese government. The decline in the rural population due to urbanization has resulted in significant increases in domestic labor costs, and some updated policies have strictly restricted local farm production for reasons of environmental protection. All these strands have combined to make the previous cooperatives less competitive than industrial hog operations, which have greater labor allocation efficiency. As the Chinese economy has grown dramatically in recent decades, consumers' taste preferences have changed accordingly. The demand for protein products, especially pork, has increased. However, it is difficult for individual hog farmers to standardize their pork products and provide quality assurance. Combined with increased labor costs, this factor makes Chinese domestic pork products less competitive than imported pork products in terms of both quality and price.

According to the dataset from the United States Department of Agriculture (USDA), the United States started exporting pork products to China in 1989. In the current study, we explored the pork export data to mainland China and Hong Kong. Figure 1 presents 60 annual observations of the past thirty years and shows an overall increase in export trends. This data provided essential background to our study as it shows that trade activities between the two countries have existed for thirty years (even with a discontinuing trade trend before 2000). Our study mainly focused on the period from 2000 to 2014. The monthly export rates from January 2000 to December 2014 are shown in Figure 2. Once again, the overall trend showed a continuous increase.

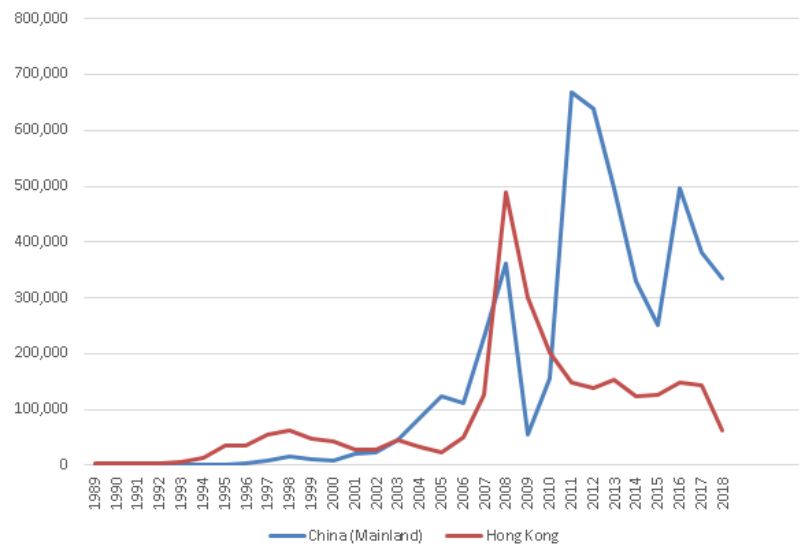

Figure 1. USDA annual pork exports to mainland China (Blue) and Hong Kong (Red) from 1989 to 2018.

Note: Unit is carcass weight, 1,000 pounds.

Data Source: https://www.ers.usda.gov/data-products/livestock-and-meat-international-trade-data/

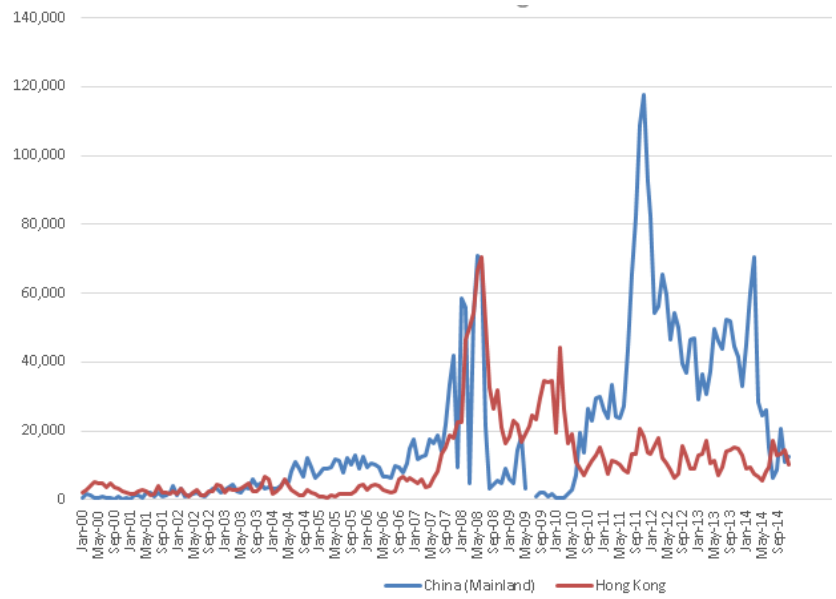

Figure 2. USDA monthly pork exports to mainland China (Blue) and Hong Kong (Red) from 01/2000 to 12/2014.

Note: Unit is carcass weight, 1,000 pounds.

Data Source: https://www.ers.usda.gov/data-products/livestock-and-meat-international-trade-data/

We included Hong Kong in our study due to the region's unique administrative characteristics. As a duty-free trade region, most of the pork was exported from Hong Kong to mainland China. An abnormally high volume of pork exports to mainland China in 2011 (shown in Figure 2) caught our attention. After examining previous studies, we found that the pork price in China increased dramatically during this time, and that Chinese pork prices rose to a new record high in 2011. The main reason for China's surge in pork imports was that the government had continuously increased its grain purchases in order to secure farmers' profits (Gale et al., 2012). This could have caused a rapid increase in domestic feed cost. The average cost of Chinese hog production increased, while the cost of hog production in the U.S. was much lower. Such significant cost and price gaps made the price advantage of imported U.S. pork more obvious.

Many previous studies (Hayes and Clemens, 1997; Wang et al., 1998; Pan and Kinsey, 2002; Fabiosa, 2005; Schneider, 2017; Ortega et al., 2017) have stated that China has never completely opened its pork import market to the United States because of China's zero tolerance for ractopamine in pork. Ractopamine is a feed additive commonly used by U.S. pork producers to simulate lean meat growing. Moreover, China started to promote the Belt and Road Initiative (BRI) involving 152 countries in Asia and Europe. There were 16 European countries already dealing with China under the BRI framework. One of the objectives of the initiative was to encourage European countries to export more agricultural products to China, and for China to invest more in infrastructure building. This also shows the determination of China to decrease previous heavy reliance on U.S. pork imports.

The objectives of this study were two-fold. First, we wanted to examine the market integration in pork prices of China and the United States and establish whether this integration existed between 2000 and 2014.

2. Literature review

2.1 Market analysis

Hayes and Clemens (1997) stated that the increased cost of grains and oilseeds made U.S. pork prices much more competitive. They also found that the taste preference for pork was highly complementary between the two countries. Chinese consumers preferred consuming pork products undervalued in the Western community. However, such products were highly valued in the Chinese community. The authors anticipated that the U.S. would have a large competitive advantage in supplying a large volume of these products at an acceptable price and that the Chinese government would open its market for these pork products. Many similar studies have explored the agricultural structure in China and pointed out the potential for trade between China and the United States (Wang et al., 1998; Pan and Kinsey, 2002; Fabiosa, 2005; Schneider, 2017; Ortega et al., 2017).

2.2 Cointegration and error correction model

Some previous studies have presented different ways to test the degree of market integration. Engel and Rogers (1996) stated that border effects were the essential determinants of international food price differences. Based on an analysis of distance hindering the tradability of products between the U.S. and Canada, they concluded that nominal currency adjustment plays an important role in driving cross-border measures.

The conceptual market integrations are both vertical and horizontal, with industrial integration represented by vertical integration and the spatial market represented by horizontal integration. Spatial market integration reflects how a price change in one market leads to a price change in another market. Market integration across different regions is discussed using various approaches. The transmission of spatial price reflects that a price adjustment is transmitted from one market to another overnight, while the law of one price explains that the prices of homogenous goods should differ by less than the transaction costs between two locations and stipulates that traders may engage in arbitrage if this condition is violated (Fackler and Goodwin, 2001). However, traders may take time to respond to price changes, and a lag may occur between the price change in one market and its reflection in another market.

Ravallion (1986) developed a dynamic regression econometric model to examine the degree of market integration of two non-stationary price processes. This model assumes that, if markets are integrated, a price change in one market will transmit to the other market instantaneously. The model could be interpreted as a vector autoregressive model, which tests the restrictions of a reduced-form parameter. The dynamic regression model is a dynamic version of a standard regression model and an alternative for the Granger causality tests (Granger, 1983).

Barrett and Li (2002) suggested applying cointegration when the given trade flow data showed discontinuities. This study shows that error correction is unreliable when the traction costs are non-stationary. We would expect the U.S. export pork price change to induce a Chinese domestic pork price change to the same degree if these two markets are perfectly integrated.

Many previous studies (Goodwin and Piggott, 2001; Sephton, 2003) have discussed the essential role of using the error correction model (ECM). A key feature of the ECM is that it is

straightforward to infer the long-run or equilibrium relationship between estimates and the vector pair includes the set of explanatory variables the relationship when neither variable tends to change. Balcombe et al. (2007) examined the price transmission and found threshold effects only exist between the U.S. and Brazil, but no exist between Argentina and Brazil when examining three countries by estimating error correction model on monthly corn price series.

3. Methodology

In this section we present an econometric model of pork prices series between China and the United States by adapting the vector error correction model (Enders and Siklos, 2001; Enders, 2010). We first examine the cointegration relationship between the two prices. If cointegration exists, we then proceed to estimate the error correction model with the seemingly unrelated regression (SUR) model.

First, we define the log Chinese hog price as P1t and the log U.S. hog price as P2t, both converted to USD. The long-run relationship, if any, can be represented as:

(1) $P_{1t} = \beta + \beta_1 (P_{2t}) + \varepsilon_t$

Because most market price series are non-stationary during their lifespan for the price processes compared in different markets. The hog price series is a random walk non-stationary process. The stochastic process is strictly stationary if all the random variables have the same distribution and the joint distribution of any two random variables with different time periods are the same. Therefore, to test if P1t and P2t are cointegrated, we conduct an augmented Dicky-Fuller test on the residual term ε_t:

(2) $\Delta\hat{\varepsilon_t} = \delta_1 \hat{\varepsilon_{t-1}} + \delta_2 \Delta\hat{\varepsilon_{t-1}} + \mu_t$

The null of the ADF test with intercept is a unit root without drift, and the alternative is a stationary process. The lagged term in the regression output is the control for the serial correlation. If the ADF test is shown to be significant, then we would expect the two markets to be cointegrated. Through the cointegration analysis, we shall explore the long-term relationship of pork prices between China and the U.S. If cointegration is found between the two price series, we can proceed an run the error correction model by including the residuals in the VAR model.

$$(3)\quad \Delta P_{1t} = \delta_{10} + \delta_{11}\hat{\varepsilon}_{t-1} + \sum_{n_1=1}^{N_1}\theta_{1,n_1}\Delta P_{1,t-n_1} + \sum_{n_2=1}^{N_2}\phi_{1,n_2}\Delta P_{2,t-n_2} + \mu_{1t}$$

$$(4)\quad \Delta P_{2t} = \delta_{20} + \delta_{21}\hat{\varepsilon}_{t-1} + \sum_{n_1=1}^{N_1}\theta_{2,n_1}\Delta P_{1,t-n_1} + \sum_{n_2=1}^{N_2}\phi_{2,n_2}\Delta P_{2,t-n_2} + \mu_{2t}$$

Equations (3) and (4) above compromise the first order of VAR with error term $\hat{\varepsilon}_{t-1}$, where $\hat{\varepsilon}_{t-1}$ is obtained from (2).

To ensure that the estimated residuals of our ECM comes close to white noises, we shall need to adjust the lag lengths longer to make sure it accesses its adequacy. Here, we use a seemingly unrelated regression (SUR) method to efficiently estimate the VECM model (Lence and Plastina, 2020).

4. Data

The Chinese hog market price data were collected from China's National Bureau of Statistics and the U.S. hog prices were collected from the USDA website. The monthly market cash prices from January 2000 to December 2014 were examined and a total of 180 observations of time series data were collected from each market. We assumed that the monthly price data were appropriate if the distance between two markets was large and the time series was long-run integrated.

Some modifications were made to assure the unity of the prices. The "CN-CNY" price series indicates the Chinese pork market price in CNY per kilogram, while "US-USD" represents the U.S. pork price in dollars. These adjusted figures are presented in Table 1.

Variable name	**Observation**	**Mean**	**Std**
China pork price in CNY	180	10.574	3.955
U.S. pork price in USD	180	1.012	0.258
Exchange rate CNY-USD	180	0.137	0.016
China pork price in USD	180	1.510	0.713

Table 1. Summary statistics.

Figure 3 shows hog prices from January 2000 to December 2014 for China and the U.S. There was an abnormally high volume of pork exports to Mainland China in 2011, while the pork price during the equivalent period in China increased dramatically. Chinese pork prices started to rose to a new record high in 2011.

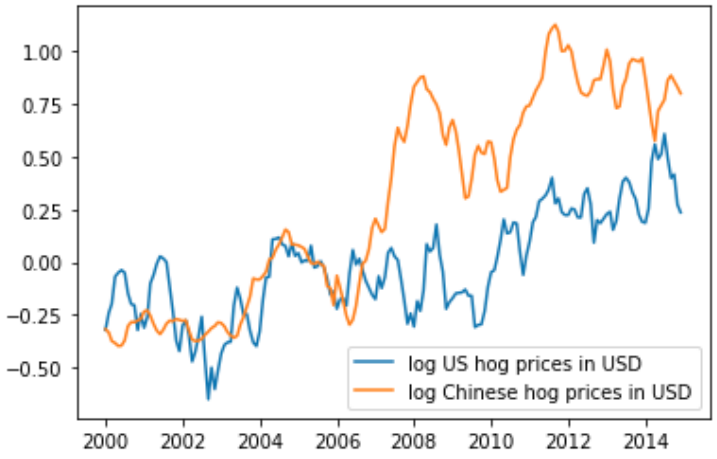

Figure 3. Hog log prices in China (yellow) and the U.S. (blue) from 01/2000 to 12/2014.

*China spot price was converted into USD by multiplying each by the corresponding exchange rate.

5. Results

5.1 *Stationarity test*

Several estimated results are presented below. First, a stationary test was conducted. The results show adjusted prices are non-stationary price series, as shown in Table 2. This is because most market price series are non-stationary during their lifespan for the price processes compared in different markets.

Value input	**P-Value**	**Result (at 5%)**
US-USD	0.643	non-stationary
CN-USD	0.734	non-stationary

Table 2. Stationary test of pork prices for China and the U.S.

5.2 *Cointegration test*

We obtain the residuals and run the ADF test for stationarity. The results are shown below.

$$(5)\ \Delta\hat{\varepsilon}_t = \underset{(0.026)}{-0.086}\ \hat{\varepsilon}_{t-1} + \underset{(0.072)}{0.268}\ \Delta\hat{\varepsilon}_{t-1}$$

With one lag of the errors included, we reject the null hypothesis of the ADF test and conclude that the errors are stationary such that the two-price series are cointegrated. Such result suggests a long tern cointegration relationship occurs in between China and the U.S. pork prices.

5.3 *Error correction model*

We can then proceed to run the error correction model. The coefficient of the error correction terms indicate the speed of adjustment, as shown below, one unit of deviation from the

long-run equilibrium in period t-1 will cause the Chinese hog price to decrease 0.021, and the US hog price to rise 0.033 units.

$$(6)\ \Delta P_{1t} = \underset{(0.004)}{0.006} - \underset{(0.012)}{0.021}\ \hat{\varepsilon}_{t-1}$$

$$(7)\ \Delta P_{2t} = \underset{(0.006)}{0.003} + \underset{(0.017)}{0.033}\ \hat{\varepsilon}_{t-1}$$

6. Conclusion

This study explored the market integration of hog markets for the two largest hog markets in the world. The results reveal a strong cointegration relationship in pork prices between China and the U.S., indicating that arbitrage does not exist in either market in terms of pork prices. Therefore, we discuss the potential influencing factors below.

Firstly, the cointegration results show the long-term price relationship, for which feed prices may help explain the market integration. The high cost of grain made U.S. pork prices much more competitive in China. Many previous studies (Hayes and Clemens, 1997; Wang et al., 1998; Pan and Kinsey, 2002; Fabiosa, 2005; Schneider, 2017; Ortega et al., 2017) have stated that China has no advantages in feed cost, and the increased cost of domestic feed makes U.S. pork prices much more competitive than locals. As a grain-deficit country, China buys more pork from grain-surplus areas, such as the U.S. Urbanization has had a significant impact on Chinese people's living standards and diet, and their increased consumption of high-quality meat products has led to a significant increase in demand for livestock feed (Schneider 2011). Maize and soybean form the main ingredients in pork feed, and as China's domestic grain prices continue to rise, causing the country to struggle to maintain its self-sufficient policy on grain imports, it has become heavily

reliant on the international commodity market for soybean. Indeed, soybeans have become the largest agricultural commodity imported by China, constituting nearly half of the international soybean trade in 2013 (USDA 2013).

In China, feed cost is regarded as the largest input cost in hog operation and usually comprises 60% to 70% of the total operation costs, and increasing feed costs would reduce feed inputs significantly(Somwaru et al., 2003; Mu, 2018), which is why the Chinese government has continued to subsidize domestic hog production and kept feed costs low by importing relatively low-priced grain, such as soybean, from the U.S. (Xiao et al., 2012). In a previous study, Zhou and Koemle (2015) investigated price transmission in China's pork and feed prices and concluded that a long-term cointegration relationship existed between China's pork price and the U.S.'s soybean futures contract prices between 2000 and 2014. Therefore, we argue that such an empirical finding may explain our results.

While several previous studies (Tang et al., 1992; Moosa, 1996; Rosenberg and Traub, 2006) have explained the essential role of the futures market in pork production, China did not have a pork futures market in the period covered by the present study. Theoretically, profitable arbitrage opportunities will never occur in an efficient market. This is because cash prices and futures prices will always adjust instantaneously in response to information. The futures market in the U.S. is mature, strong, and has many positive characteristics such as excellent transparency, high liquidity and leverage, and relatively low-cost transactions. Nonetheless, In 2012, publicly-traded Chinese multinational meat and food processing company, WH Group (formerly Shuanghui Group), acquired Smithfield, which is known as one of the largest pork companies in the U.S. This acquisition allowed WH Group to import more frozen pork from the U.S. to China and acquire advanced technologies, such as machineries. WH Group used its imported frozen pork from the

U.S. to downsize its domestic hog farms in China because of the imported meat's low production cost and high quality (Zhang et al., 2017). Although China has a relatively vulnerable financial market, companies such as WH Group are increasing the number of trade channels; thus, in 2017, the Chinese government announced that it would launch China's hog futures market within five years.

In conclusion, the empirical results from previous studies may help to explain the transmission of soybean price linkages to the cash pork price in China. In addition, we compare the differences in current financial markets, acknowledging that, in the period covered by our study, China did not have its own futures market for pork, but trade flow increased after WH Group acquired one of the biggest pork companies in the U.S. These two potential factors may help to explain our results to some degree.

References

Balcombe K, Bailey A, Brooks J (2007) Threshold effects in price transmission: the case of Brazilian wheat, maize, and soya price. Am J Agric Econ 89:308–323

Barrett, C., and J. R. Li. 2002. Distinguishing between equilibrium and integration in spatial price analysis. American Journal of Agricultural Economics 84 (2): 292–307.

Enders W (2010) Applied econometric time series. Wiley, New Jersey

Enders W, Siklos P (2001) Cointegration and threshold adjustment. J Bus Econ Stat 19:166–176

Enders W, Granger CWJ (1998) Unit-root tests and asymmetric adjustment with an example using the termstructure of interest rates. J Bus Econ Stat 16:304–331

Engel, Charles and John H. Rogers 1996. "How Wide Is the Border?" Amer. Econ. Rev. 86:5, pp. 1112–25.

Engle, Robert F. and C.W.J. Granger, 1987, Cointegration and error correction: Representation, estimation and testing, Econometrica 55, 251-276.

Fabiosa, J.F. 2005. "Growing Demand for Animal-Protein-Source Products in Indonesia: Trade Implications," CARD Working Paper 05-WP 400, Center for Agricultural and Rural Development, Iowa State University.

Fackler, P.L. and B.K. Goodwin. 2001. "Spatial Market Integration." In B.L. Gardner and G.C. Rausser, eds., Handbook of Agricultural Economics, Vol. 1, Ch. 17. Amsterdam: North Holland, pp. 971- 1024

Fuller, W.A. 1976, Introduction to statistical time series (Wiley, New York). Granger, C.W.J., 1981, Some properties of time series data and their use in econometric model specification, Journal of Econometrics 16, 121-130.

Gale, Fred, Sophia Huang, and Yingying Gu. Investment in Processing Industry Turns Chinese Apples Into Juice Exports, FTS-344-01, USDA, Economic Research Service, 2010.

Gale, Fred, Daniel Marti, and Dinghuan Hu. China's Volatile Pork Industry, LDPM-211-01, USDA, Economic Research Service, 2012.

Granger, C.W.J. and A.A. Weiss, 1983, Time series analysis of error-correcting models, in: S. Karlln et al., eds., Studies in econometrics, time series, and multivariate analysis (Academic Press, New York) 255-278.

Hayes, D.J., and Roxanne Clemens, "The Chinese Market for U.S. Pork Exports," Iowa State University CARD Briefing Paper 97-BP 14, March 1997.

Lence, S. H., & Plastina, A. (2020). An Empirical Investigation of Productivity Spillovers along the Agricultural Supply Chain. An Empirical Investigation of Productivity Spillovers along the Agricultural Supply Chain.

Moosa IA (1996) An econometric model of price determination in the crude oil futures markets. In: Proceedings of the econometric society Australasian meeting vol 3, pp 373–402

Mu,Y.,2018.PorkpricetransmissionandefficiencyinChina.In:Paperpreparedforpresentationatthe30thICAEconference.Vancouver,Canada

Ortega, D. L., Chen, M., Wang, H. H., & Shimokawa, S. (2017). Emerging markets for US pork in China: Experimental evidence from mainland and Hong Kong consumers. Journal of Agricultural and Resource Economics, 42, 275–290.

Pan, C., and J. Kinsey. 2002. "The Supply Chain of Pork: U.S. and China." Working Paper 02-01. The Food Industry Center, University of Minnesota.

Porteous, O.C. Forthcoming. "High Trade Costs and Their Consequences: An Estimated Dynamic Model of African Agricultural Storage and Trade." American Economic Journal: Applied Economics.

Ravallion, M., 1986, 'Testing Market Integration', American Journal of Agricultural Economics pp. 102-9.

Rosenberg J V, Traub L G (2006) Price discovery in the foreign currency futures and spot market. Federal Reserve Bank of New York Staff Reports, No. 262

Schneider, M. 2017. "Dragon Head Enterprises and the State of Agribusiness in China." Journal of Agrarian Change 17 (1): 3–21.

Somwaru, A., Zhang, X., Tuan, F., 2003. China's hog production structure and efficiency. In: American Agricultural Economics Association Annual Meeting, p.29.

Tan, Y. and Zapata, H.O. (2014), "Hog price transmission in global markets: China EU and US", 2014 Annual Meeting No. 162540, Southern Agricultural Economics Association, Dallas, TX, February 1–4.

Tang YN, Mak SC, Choi DFS (1992) The causal relationship between stock Index futures and cash Index prices in Hong Kong. Appl Financ Econ 2:187–190. doi:10.1080/758527099

Wang Q, Fuller F, Hayes D, Halbrendt C. Chinese consumer demand and for animal products and implications for US Pork and poultry exports. J Agricultural and Applied Economics. 1998; 30: 127–140.

Xiao H, Wang J, Oxley L, Ma H. 2012. The evolution of hog production and potential source for future growth in China. Food Policy, 37, 366–377.

Yu, Y., K. Feng, K. Hubacek, and L. Sun. 2016. Global implications of China's future food consumption. Journal of Industrial Ecology 20(3): 593–602.

Zhang, Y. , Rao, X. , & Wang, H. H. (2017). Organization, technology and management innovations through acquisition in China's pork value chains: The case of the Smithfield acquisition by Shuanghui. Food Policy, 83, 337–345.

Zhou D., and D. Koemle. (2015), Price Transmission in Hog and Feed Markets of China. Journal of Integrative Agriculture 14, pp. 1122-1129 [accessed 23.02.2016].